THEORY GROUP THOUGHTS ON FUTURE (AND CURRENT) EXPERIMENTS

OR

YOUR LUNCH-TIME ENTERTAINMENT

Summarizer: Frank Petriello

ANL retreat
December 15, 2010

Goals of the talk

- Meant to generate discussion and audience input
- What was asked of theory group members:
  - What do you think are the most interesting experiments that the entire particle physics field should pursue in the next 10 years?
  - What role do you see for ANL in these efforts? Which are the most important to pursue and why?
  - How would your research direction be affected if ANL got involved in these experiments?
- Additional item answered: what measurements do you think it is important to pursue at the LHC+upgrades?

Big questions

- What is the origin of electroweak symmetry breaking?
- What comprises the dark sector of the universe?
- What explains the matter-antimatter asymmetry in the universe?
- Is there an explanation for the differences in the quark and lepton flavor sectors? Why does an extreme range of Yukawa couplings exist?

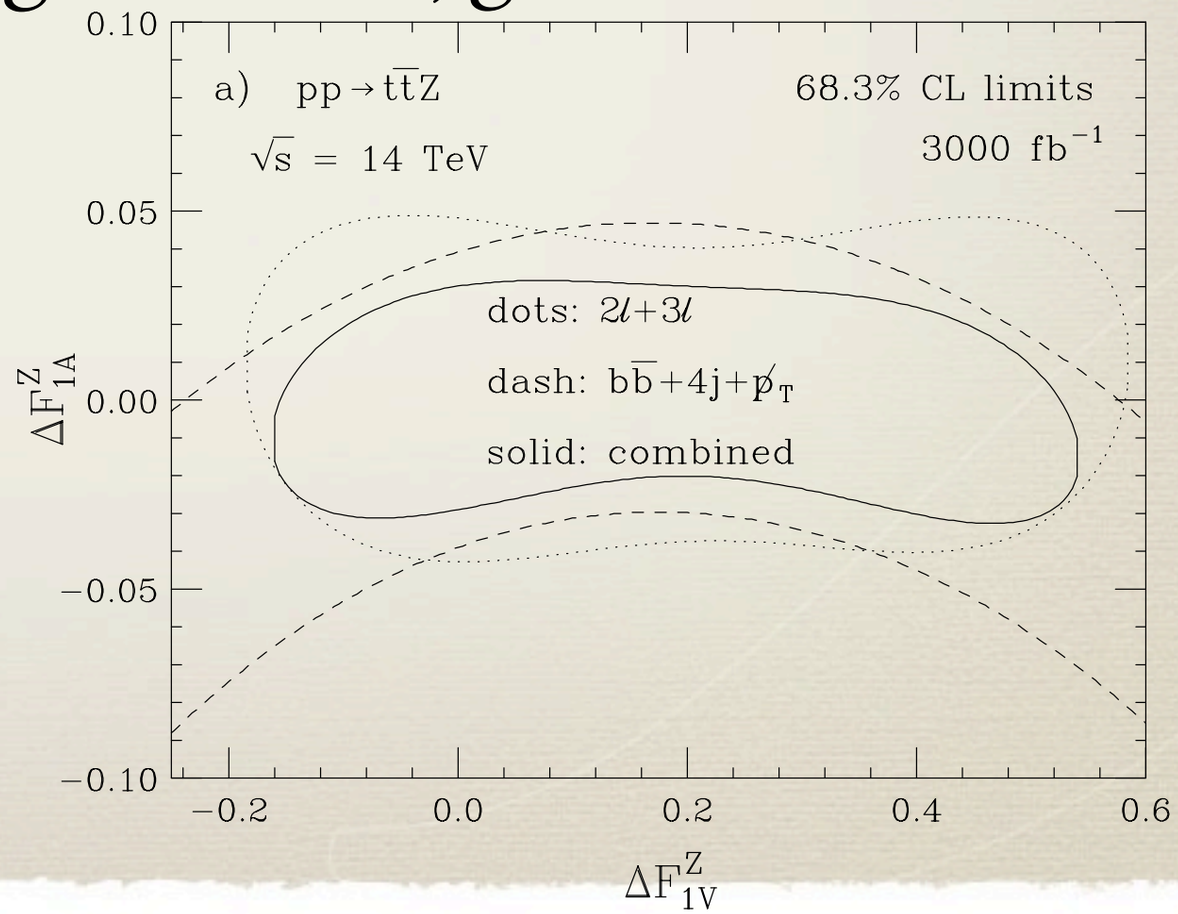
Experimental hints

- Excellent agreement of LEP/SLC data with Standard Model ⇒ severe restriction on SM extensions
- Convincing evidence for dark matter

LHC studies

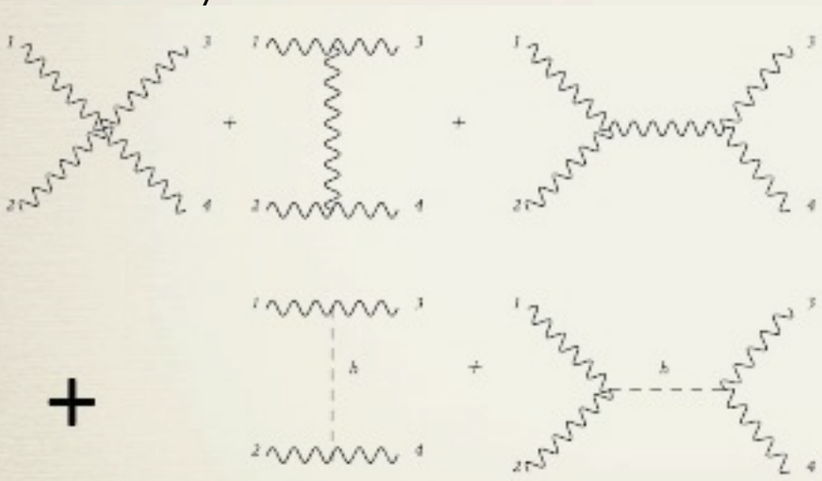
Obvious things at the LHC

- Find or exclude the SM Higgs!
- Are there any new resonances?
- Multi-jets/leptons+missing E_T: SUSY, generic dark matter signature
- Don't know top-quark EW couplings!



WW scattering (Cosmas)

- Strongest theoretical argument needing a Higgs; without one, need something else to unitarize. Answer likely to be encoded in WW scattering.



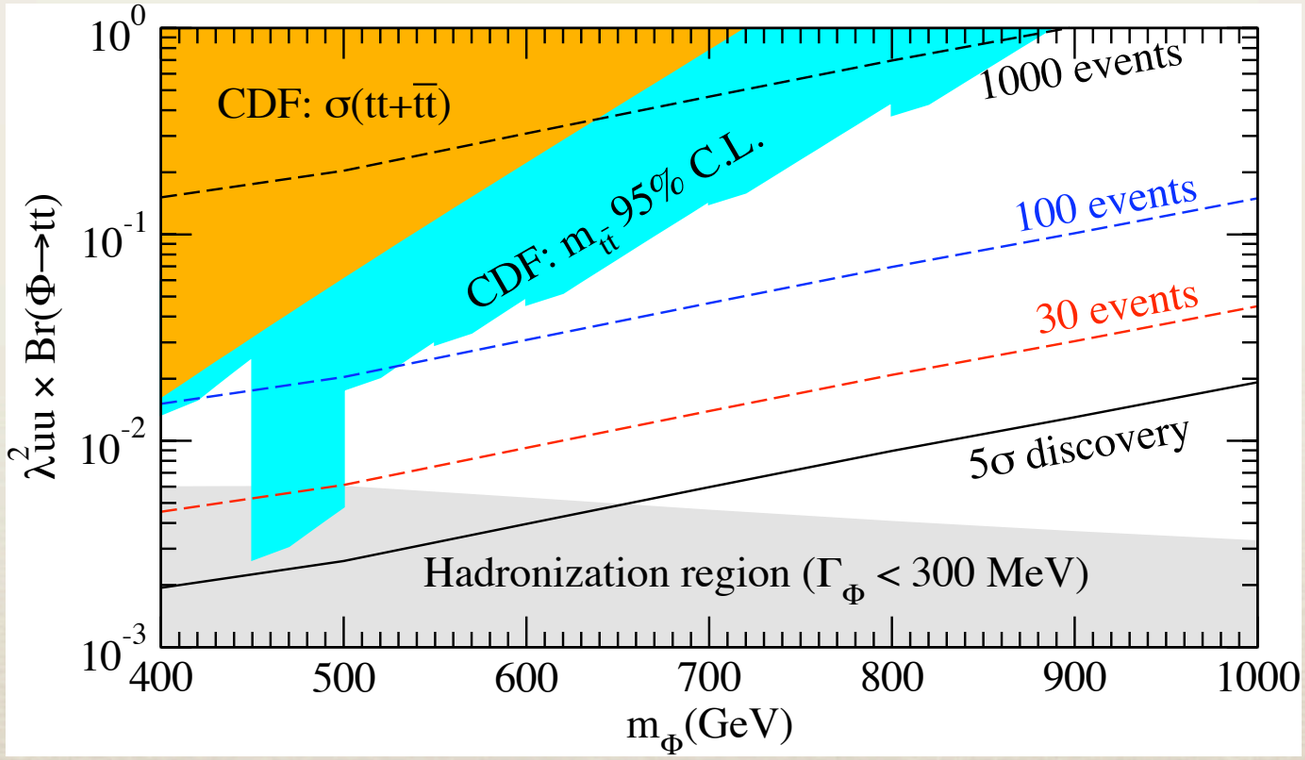
$$\mathcal{L}_{eff} = \mathcal{L}_2 + \mathcal{L}_4 + \mathcal{L}_6 + \ldots, \quad \mathcal{L}_n = \mathcal{O}(p^n)$$

$$\begin{aligned}\mathcal{L}_2 \;=\; & \frac{1}{4}v^2\mathrm{tr}(\hat{D}_\mu\hat{U}^\dagger\hat{D}_\mu\hat{U}) - (\bar{\rho}-1)\frac{v^2}{8}\left[\mathrm{tr}(\hat{T}\hat{V}_\mu)\right]^2 \\ & + \frac{1}{2g^2}\mathrm{tr}(\hat{W}_{\mu\nu}\hat{W}_{\mu\nu}) + \frac{1}{2g'^2}\mathrm{tr}(\hat{B}_{\mu\nu}\hat{B}_{\mu\nu})\end{aligned}$$

- Study WW scattering in vector-boson fusion; look for deviations from SM
- High luminosity measurements⇒keep pursuing LHC

Unexpected opportunities (Ed, Qinghong)

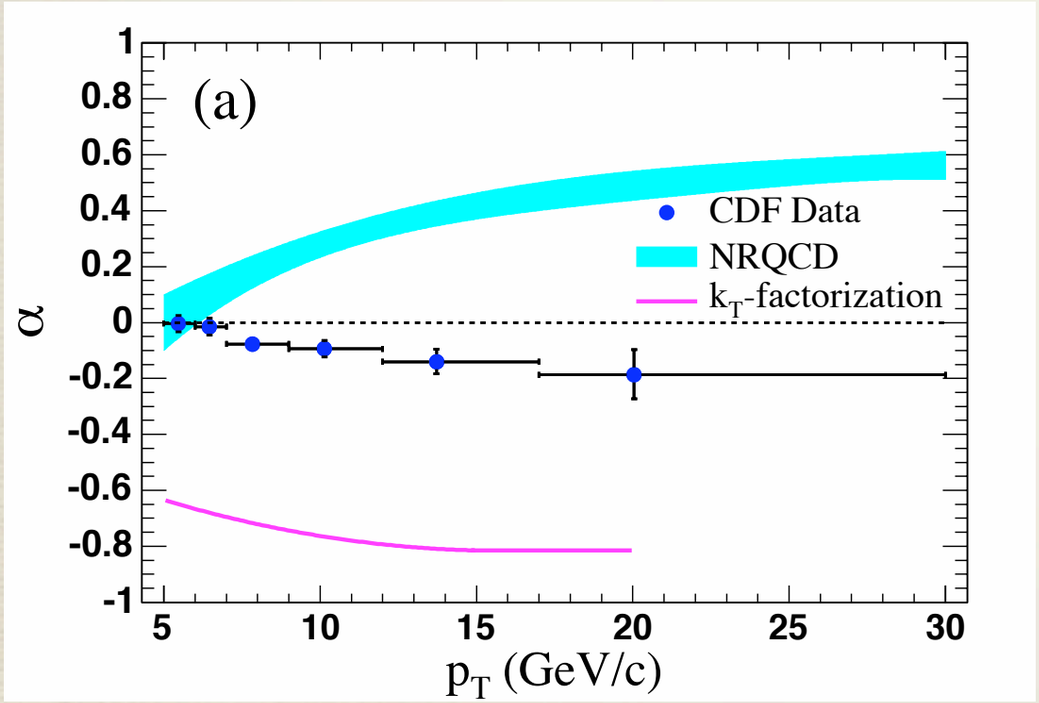
- New physics with big cross sections, low backgrounds could be discovered early; don't miss them!
- Example: color sextet, octet bosons. Color-sextets decay to same-sign tops.



7 TeV, 1 fb^{-1}

Probes of QCD dynamics (Geoff)

- We rely on factorization for making all hadron-collider predictions; a question whether non-relativistic QCD describes quarkonium production at Tevatron



J/ψ polarization not described by NRQCD; disagreements between CDF and Do data

- Can ATLAS measure polarization in direct production at high p_T?
- Measurements should be differential in rapidity also at high momentum (QCD can predict this)

Bread and butter (Seth)

- Many important, fundamental measurements at Tevatron weren't updated at higher luminosities

Z(->ee) forward-backward asymmetry	A_FB consistent with SM (chi2/DOF 10.2/12)	364 pb^{-1}	Public Note
Z(->tau_h tau_e) cross section	σ(ppbar->Z) = 264 ± 23 (stat) ± 14 (sys) ± 15 (lum)	350 pb^{-1}	PRD 75, 092004
W cross section with forward electrons	σ(ppbar -> W) = 2.796 ± 0.013 (stat) + 0.095 - 0.090 (syst) ± 0.168 (lum) nb	223 pb^{-1}	PRL 98, 251801 (hep-ex/0702037)

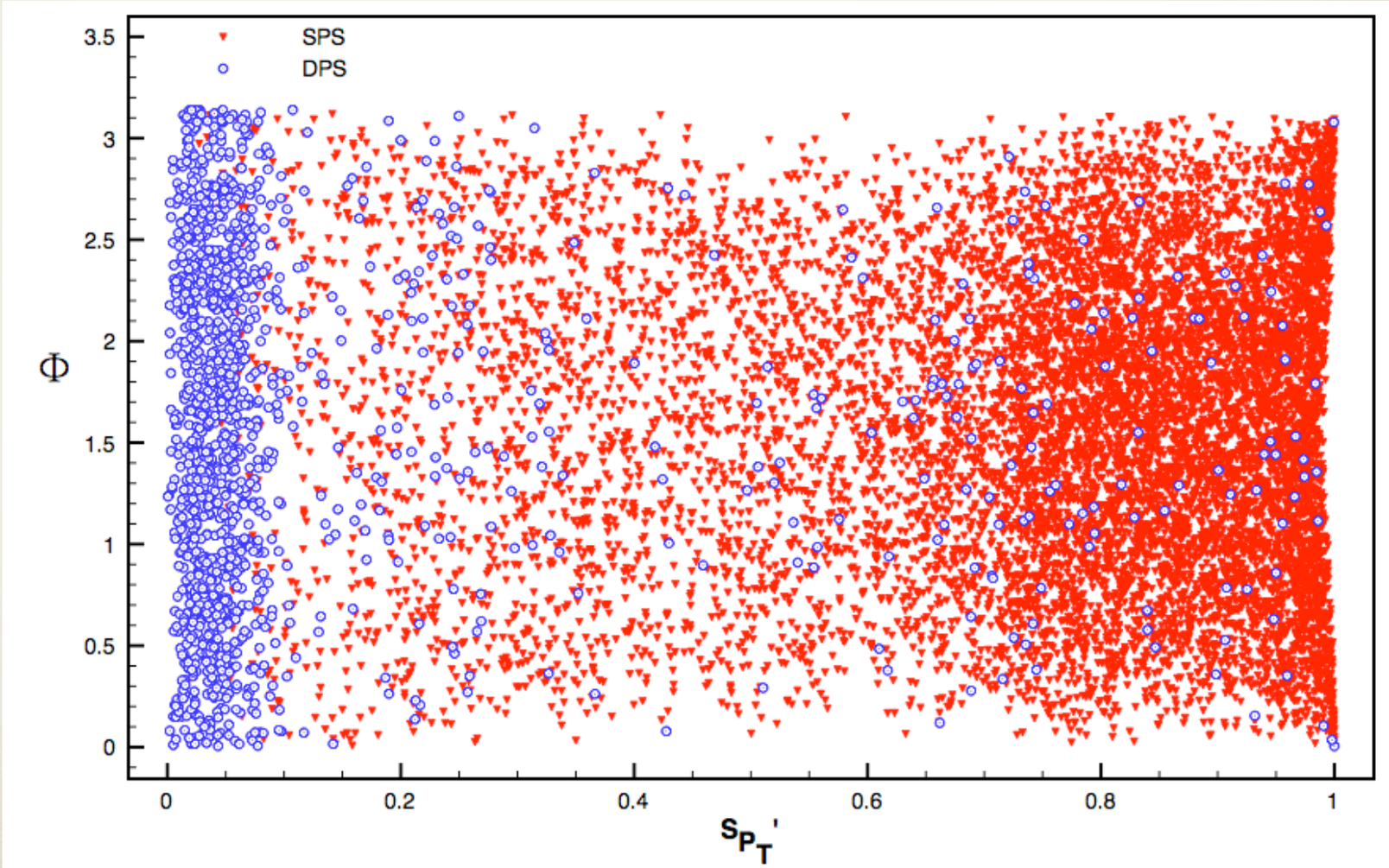
Possible PDF constraint

- W cross section measured in muon channel, Figures, 3/10/05, 96 pb-1
- Measurement of W→en and Z→ee Cross Sections, Figures; 8/13/04, 177 pb-1
- Measurement of Z→mm Cross Section, Figures; 8/11/04, 148 pb-1

- Did collaborations ever attempt to monitor luminosity with the W/Z cross section measurements?

Double-parton scattering (Ed)

- Claim that DPS contribution can be measured in pp→bbjj



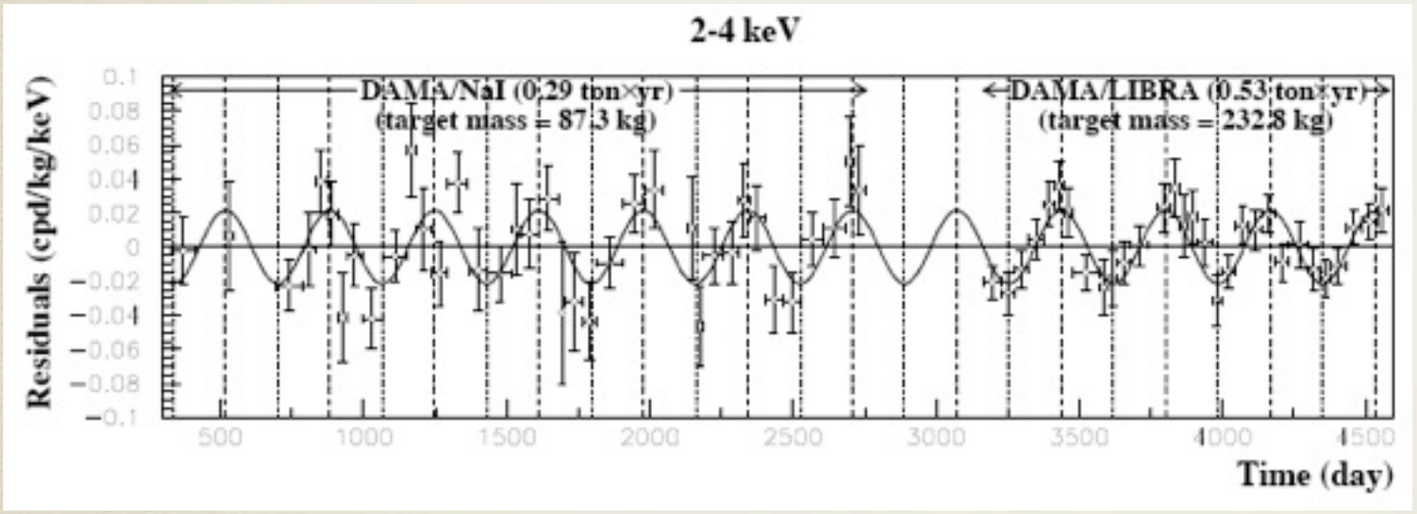
Future experiments

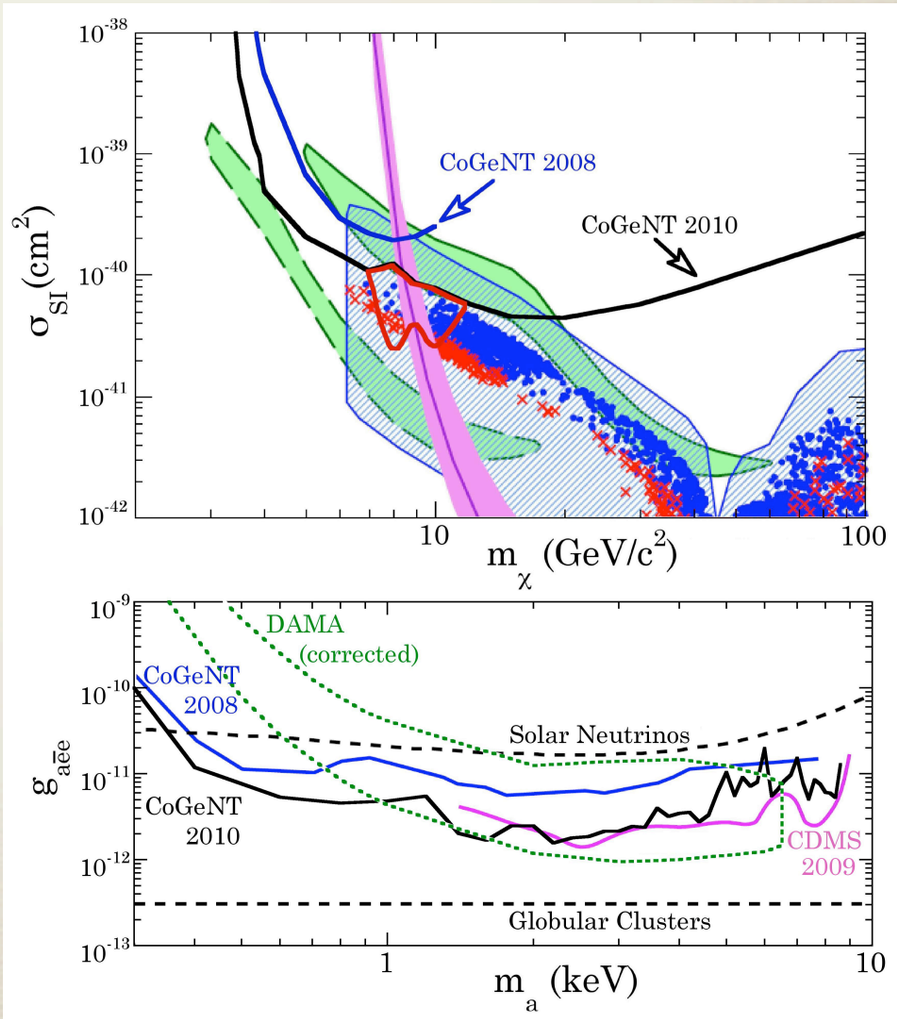
Future linear colliders

- Assuming Nature is kind, a future TeV-scale linear collider will be needed to determine high-scale theory from LHC discoveries... an obvious direction for the division to continue pursuing.

Dark matter (Jamie)

- Promises to be an extremely active area for the next 10 years. Even some tantalizing hints…





Dark matter

- Dark matter searches have a strong connection with the astrophysics group activities, and are an interest of the theory group. How can the division become involved? Any direct/indirect detection experiment that we contribute to?

- Can a new annual-modulation experiment to check DAMA be performed (or is the DAMA exposure too high to redo in finite time)?

EDMs (Carlos)

- CP violation in the SM not sufficient to explain baryon-antibaryon asymmetry. Electric dipole moments are an excellent probe of new sources of CP violation.

System	Present Limit (e-cm)	Group	Future Sensitivity	Standard Model (CKM)
e^-	1.6×10^{-27} (90% CL)	Berkeley		$< 10^{-38}$
e^-		Yale	$\sim 10^{-29}$	
e^-		LANL	$\sim 10^{-30}$	
μ	1.05×10^{-18} (90% CL)	CERN		$< 10^{-36}$
μ		BNL	$\sim 10^{-24}$	
n	6.3×10^{-26} (90% CL)	ILL	1.5×10^{-26}	$1.4 \times 10^{-33} \rightarrow 1.6 \times 10^{-31}$
n		PSI	7×10^{-28}	
n		LANL	2×10^{-28}	
^{199}Hg	2.1×10^{-27} (95% CL)	Seattle	5×10^{-28}	$\lesssim 10^{-33}$
^{225}Ra		Argonne	10^{-28}	
^{129}Xe		Princeton	10^{-31}	$\lesssim 10^{-34}$
D		BNL	$\sim 10^{-27}$	

	CASE I			CASE II		
phases	d_{Tl}	d_n	d_{Hg}	d_{Tl}	d_n	d_{Hg}
ϕ_1	weakly	weakly	weakly w. small $\tan\beta$	not	not	not
ϕ_2	strongly	strongly	strongly	weakly w. small $\tan\beta$	weakly w. small $\tan\beta$	not
ϕ_3	not	strongly	strongly	not	weakly w. small $\tan\beta$	weakly
ϕ_e	weakly	not	not	not	not	not
ϕ_u	not	weakly	strongly	not	not	not
ϕ_d	not	strongly	strongly	not	not	not
ϕ_μ	not	not	not	not	not	not
ϕ_c	not	not	not	not	not	not
ϕ_s	not	not	not	not	not	not
ϕ_t	weakly	weakly	weakly	weakly	weakly	weakly
ϕ_b	not	weakly	weakly	not	weakly	weakly
ϕ_τ	not	not	not	not	not	not

SUSY phases

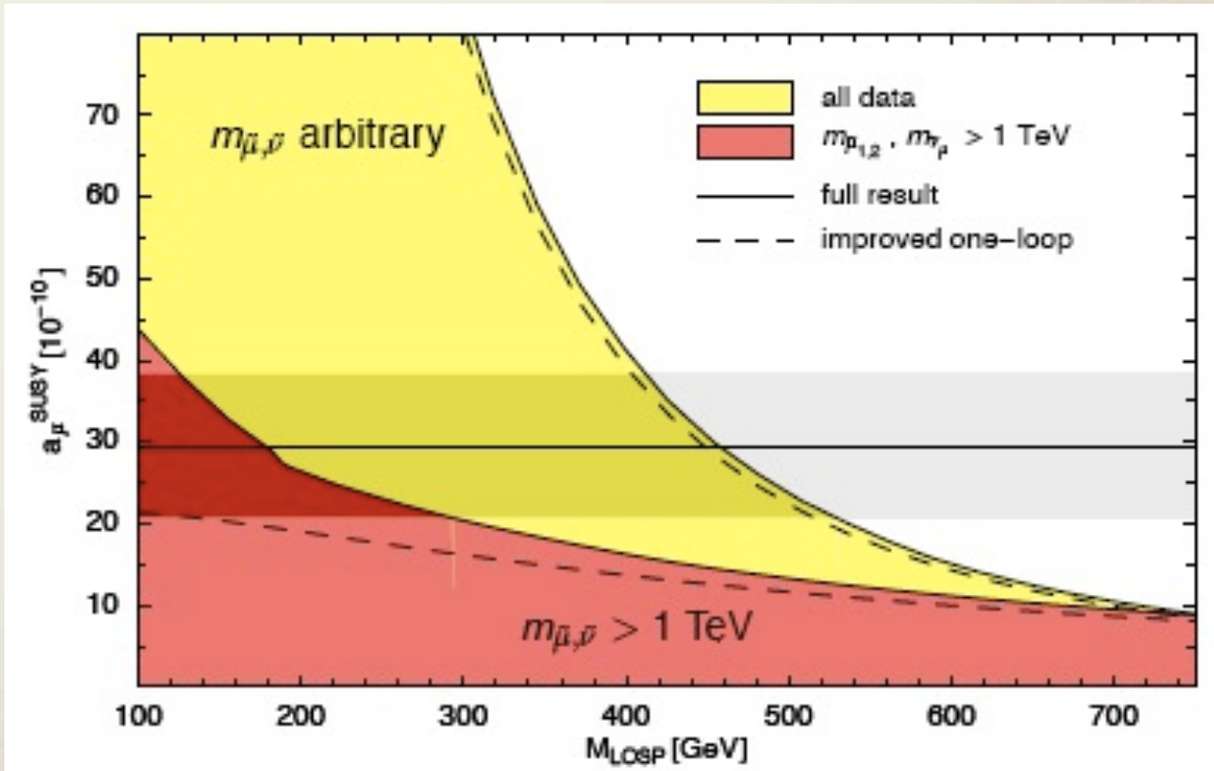
EDMs

- Proposal in the Physics division (Z.-T Lu et al.) to use radium to improve EDM searches; sensitivity to CP-odd effects expected be 3 orders of magnitude stronger than mercury. Severe restrictions on MSSM baryogenesis.

- Is there a way for HEP to get involved in this? Such low energy precision searches provide complementary information to what LHC tells us.

g-2

- Right now a 3.1σ deviation from the SM
- Theory has settled down with e^+e^- data from Frascati, Novosibirsk, no need to rely on tau and isospin
- Proposal to do at FNAL with factor of 4 smaller experimental error; improvements in theory would lead to 7σ



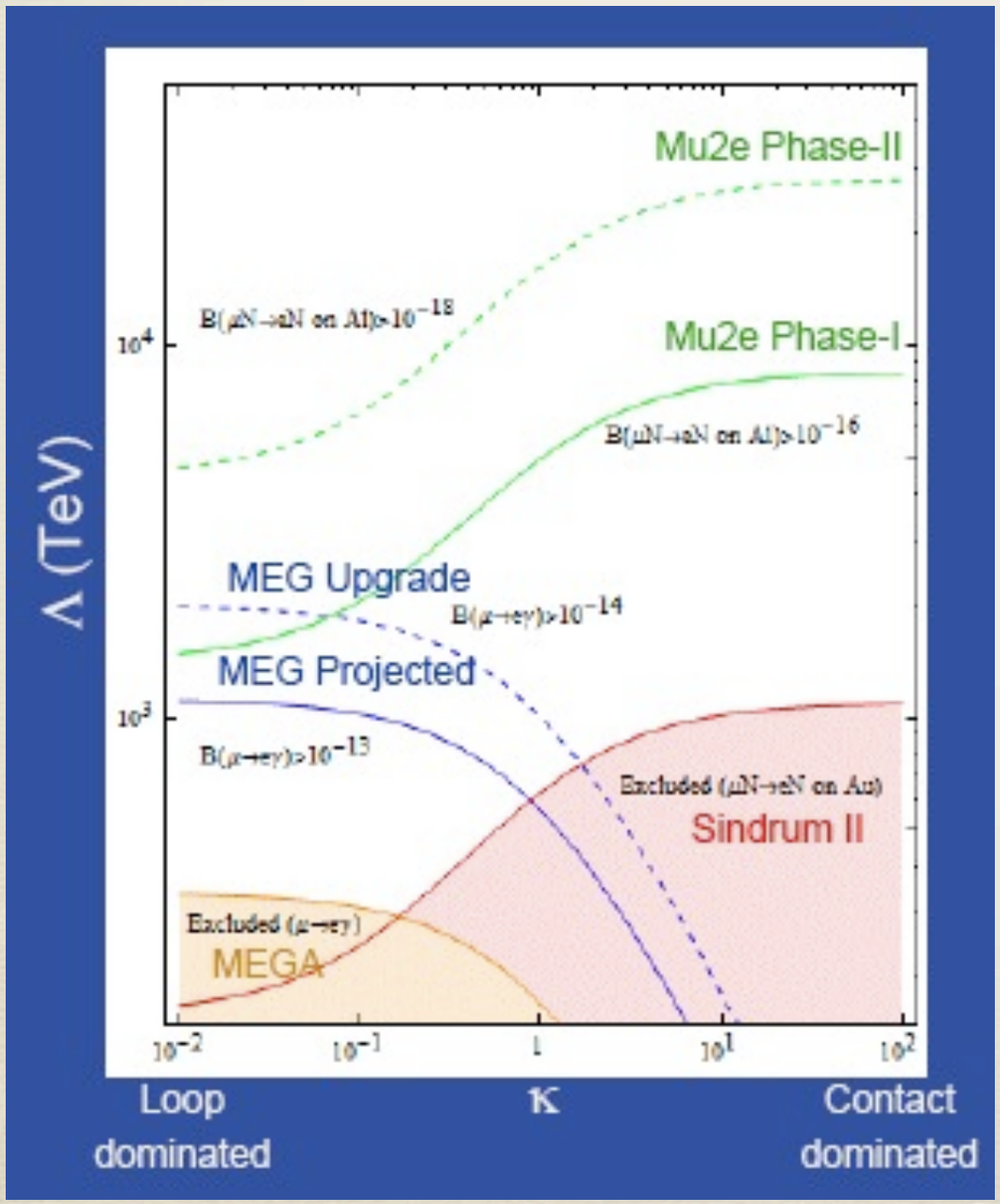
General MSSM for tan $\beta = 50$, all parameters < 3 TeV [DS '06]

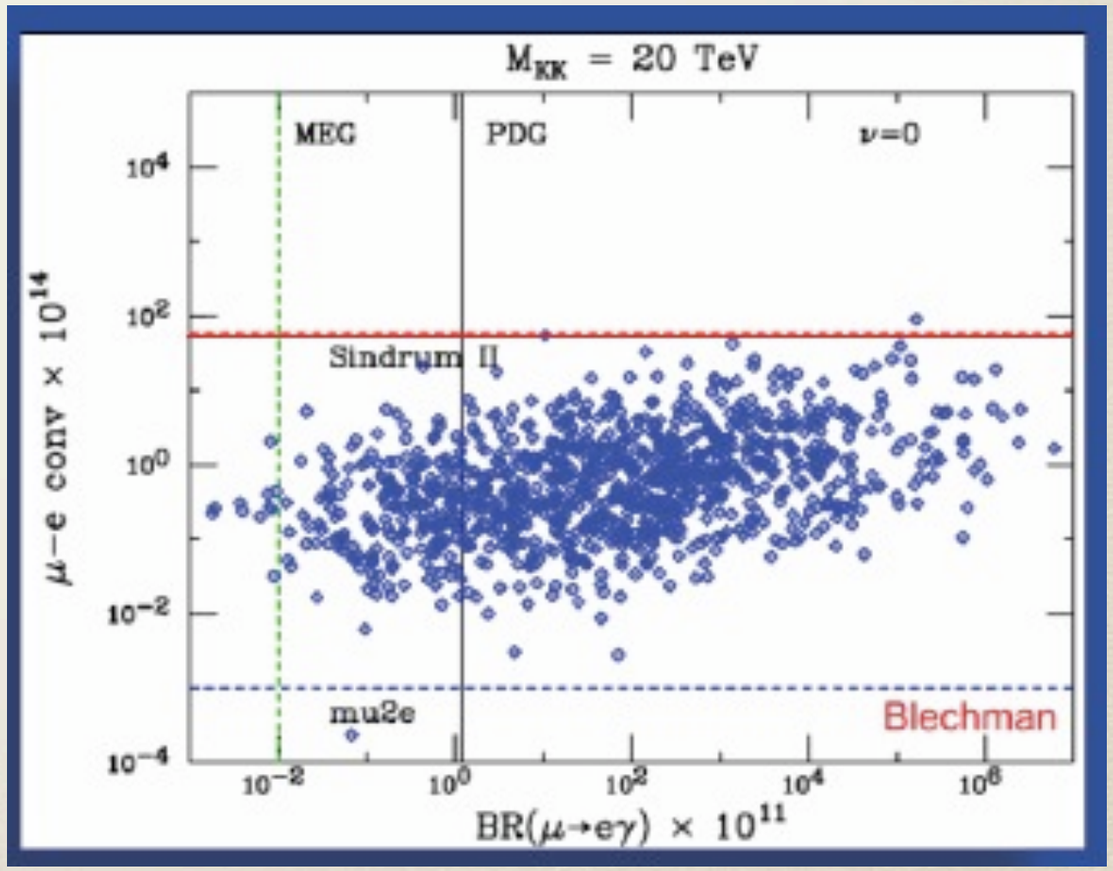
g-2

- Possibility of a major discovery here; interest in the division in getting involved? Any expertise the HEP division can offer? Overlap with the physics division?
- Definite role for theory group; both in analyzing hadronic light-by-light, thinking about how new physics can contribute... some technically challening problems to solve.

mu2e

- What about mu2e? Physics case is strong.





Conclusions

- Many exciting opportunities the division could possibly pursue.
- Some (linear colliders) depend on LHC data.
- Others (EDMs, g-2) can be done for low cost, and will provide interesting complementary information to the LHC. Potential for physics division collaboration.
- We'd like to know what the rest of the division thinks!